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Designing physical activity environments to enhance physical and psychological effects

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Abstract

Understanding how best to accrue benefits from designing physical activity and exercise programmes is needed to tackle global health problems related to physical inactivity and poor mental health. Some studies have implicated an important role for green exercise and physical activity, but there is a lack of clarity in current research. Therefore, more work is needed to understand how to design green physical activity and exercise environments that afford (invite) physical and psychological benefits to individuals. We examined whether exercising while viewing a dynamic or static image of a scene from nature would offer different affordances (invitations for behaviours to emerge), compared to the common conditions of self-selected entertainment. For this purpose, 30 participants (18 males and 12 females; age 27.5 ± 9 yrs; mass 67.6 ± 11.1 kg; stature 173.7 ± 8.2 cm) exercised in three experimental conditions in a counterbalanced design while: (i) viewing a video of a green environment, (ii) viewing a single static image of the green environment; and (iii), when using typical self-selected entertainment without viewing images of nature. A twenty-minute treadmill run was undertaken at the participants' own self-selected speed in a laboratory while energy expenditure and psychological states (using PANAS) were assessed. Results showed no differences in energy expenditure ($p > .05$) or negative affect ($p > .05$) between conditions. However, data revealed significant differences in positive affect when participants ran with a static image and their own entertainment compared to running with a dynamic image. Results revealed how differences in affordances designed into physical activity environments can shape psychological states that emerge during exercise. Further research is needed on affordance design in physical activity and exercise by engineers, designers, planners and psychologists to explore effects of a range of simulated environments, with different target groups, such as fit and unfit individuals, elderly and children.

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1. Introduction

Physical inactivity has been identified as the fourth leading risk factor for global mortality causing an estimated 3.2 million deaths globally [1], and implicated in the prevalence of non-communicable diseases such as cancers and cardiovascular defects [2]. Mental health is also at risk in modern societies, with 25% of the world's population reporting a mental disorder at some point in their lives [3]. In addition, with the rapid development of urbanisation, 54% of the world population lived in urban areas in 2014 [4]. The availability of time and suitable environments may constrain the opportunity for and the nature of physical activity undertaken. Therefore, how to promote physical activity and mental well-being for the majority of urban dwellers is a pressing issue nowadays. Exercising indoors has become increasingly popular among active people, including usage of gymnasia, sport hall and homes [5]. A growing body of literature shows that undertaking physical activity indoors with the engagement of

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nature, known as green physical activity, is a tangible method to tackle these difficulties e because of its multiple physical and psychological benefits [6–12]. For example, simply viewing nature scenes through a window during physical activity, one type of green physical activity, can have positive effects on health, pain endurances and job satisfaction [8, 9]. Running or cycling while viewing nature images can reduce blood pressure and heart rate [11], improve mood and self-esteem [12]. Although multiple benefits have been reported in some empirical studies, understanding how to best design indoor physical activity environments is an important challenge for engineers, designers, planners and psychologists to facilitate activity levels and mental health in people. In this task, a powerful theoretical framework is crucial because it can offer design principles and identify influential variables to target exercise programmes towards physical and/or psychological benefits (i.e. reduction in negative affect or enhance positive affect).

Ecological dynamics is one such framework which can support the work of multidisciplinary teams of exercise designers, advocating a powerful role for the organism-environment relationship through the continuous interaction of perceptual and action systems to regulate behaviours. The key concept of 'affordances' is important to understand how the continuous interaction of perceptual and action systems can lead to different physical and psychological states emerging in the relationship between an individual and an exercise environment [13]. Affordances are opportunities or invitations for behaviours [14] that exist in different environments to be utilised by people during goal-directed behaviours. The relationship between an individual and environment can be understood from multiple dimensions [15]. For example, a surface can be sat or stood upon (physical availability), offering relaxation and support when needed (positive psychological feelings), but it also can be viewed as a challenge to ascend (positive perception), or an obstacle or barrier to overcome (negative psychological perceptions), existing in a distinct place (physical unavailability for some people like elderly or infants). An ecological dynamics perspective has been proposed to underpin observed effects of green exercise and physical activity because of the affordances that are utilised in different activity environments [13]. From a designer's point of view, it is important to understand how to create an exercise environment which offers different affordances to be utilised, depending on the effectivities (intentions, actions, capabilities) of an individual, accruing positive rather than negative effects on behaviour. Besides, there are different constraints to coordinate when influential factors are changed, such as indoor or outdoor space, and involvement of elderly people or children.

When designing indoor physical activity environments, it is ambiguous whether there were different effects of viewing static or dynamic images of nature during green physical activity. This is because the previous work in ecological psychology has revealed differences in evaluation of environmental scenes when viewing static and dynamic displays [16]. Furthermore, the effects of these two types of affordances (visual) are not clear, when compared to the popular current method of listening to music using earphones or watching TV programmes in a gym (auditory/ visual). The aim of this study was to examine the effects of different affordances designed for physical activity on emergent physical and psychological measures during indoor exercise among young adults. The hypotheses tested were:1) that there will be no differences in physical responses between running on a treadmill with nature-based affordances, compared to running with self-selected entertainment; and 2) that people will experience and report more positive affect when they run with nature-based affordances, compared to self-selected entertainment conditions

2. Method

2.1. Participants

Thirty participants (mean ± SD: age 27.5 ± 9 yrs ; mass 67.6 ± 11.1 kg; stature 173.7 ± 8.2 cm; BMI 22.2 ± 2.1; 18 males and 12 females) were recruited and provided informed consent after receiving institutional ethical approval from the Research Ethics Committee of Sheffield Hallam University. The majority of participants were regular exercisers (self-reported around 5 hours per week).

2.2. Experimental Design

Three conditions were created. For the dynamic image condition, a nature video was recorded at the Sheffield Botanical Gardens. The video aimed to represent a first person perspective of running through the gardens and it was filmed at 5.2 mph to present a moderate exercise level [17]. The video was filmed on a sunny afternoon in April, 2015 with many visitors in the garden also present. We placed a Gopro camera (Hero3+, USA) on a helmet of a cyclist moving along a path in the gardens. Participants in Static Image Condition: viewed one static image from the video while performing a treadmill run (see Figure 1, left). In Dynamic Image Condition, participants viewed the video of running in nature while they exercised on the treadmill. Self-Selected Entertainment Condition involved participants running with their preferred, self-selected entertainment, such as listening to music or watching a TV programme on a wall-mounted monitor, as they would in a gymnasium.

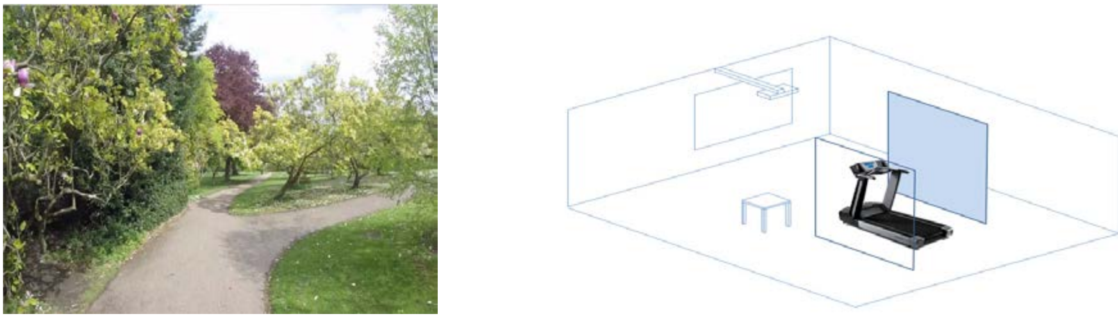

Figure 1. Left: Static Image Condition, a static image which was a frame from the dynamic image; Right: the experimental setting.

The experimental setting is shown in Figure 1(Right). The treadmill was 3 m away from the wall and the image/video was projected on to a 2×1 m screen on the wall. There were two partitions on each side of the treadmill for ensuring that the participants' visible area was not interfered with by other irrelevant distractions.

2.3. Procedure

In a counterbalanced design, all participants were asked to perform a twenty-minute treadmill run at a comfortable self-selected speed in each condition at similar time. There was at least 7 days between conditions to 'wash out' condition effects and avoid fatigue for each participant. Participants were informed that they could change their speed at any time during the run. The display screen on the treadmill was covered but participants could change their speed by pressing a button on the treadmill control panel. Before the first trial, age, mass, stature and resting heart rate were collected for estimating energy expenditure. The positive and negative affect scales (PANAS) were completed in pre- and immediately post-testing conditions [18]. The Actiheart (CamNtech, USA) was used in this study for estimating energy expenditure because its reliability and validity was well supported in existing literature [19]. The PANAS was used for measuring psychological effects, which assessed self-reported positive and negative feelings of participants before and after the exercise bout. The PANAS was a 20-item scale, divided into two separate 10-item positive and negative affect scales. Positive affect was characterised by feelings of enthusiasm, engagement, and alertness, whereas negative affect is characterized by various types of distress, including anger, contempt, disgust, guilt, fear, and nervousness. The scores were summed from the responses to the 10 items, with higher scores representing higher level of positive or negative effect on the respective sub-scales.

2.4. Data Analysis

Energy expenditure output was calculated minute by minute and the sum of the twenty-minute run was used for the analysis. The majority of self-selected entertainment involved a mix of acoustic and visual affordances, including listening to music (21 out of 30 participants) and watching TV (8 out of 30 participants). A one-way repeated measure ANOVA was used to examine differences in energy expenditure (data from 9 individuals were lost due to technical problems) and two, separate two-way repeated measures ANOVAs were used to analyse the positive and negative sub-scales of PANAS (N=30). An alpha level of 0.05 was used to indicate significant difference levels, with Partial eta squared used for effect size calculations.

3. Results

3.1. Energy Expenditure

There was no effect found for energy expenditure between conditions, $F(2, 40) = 1.511$, $p > .05$, $\eta p^2 = .07$. Table 1 shows the sum of energy expenditure in each condition.

Table 1. The sum of energy expenditure of each condition for the twenty-minute treadmill run (mean ± SD).

	Dynamic Image	Static Image	Self-selected entertainment
Kcal	161.2 ± 42.8	150.2 ± 40.8	160.5 ± 44.4

3.2. The Positive and Negative Affect Scale

Time had a main effect on positive feelings, $F(1, 29) = 18.267$, $p < .001$, $\eta p^2 = .386$ (Pre-CI, 22.944 - 28.078; Post-CI, 26.321 - 31.101).There was no main effect for condition on positive feelings, $F(2, 58) = .254$, $p > .05$, $\eta p^2 = .009$ (Dynamic-CI, 24.722 - 30.261; Image-CI, 24.298 - 30.068; Self-CI, 23.914 - 29.353). However, there was an interaction between time and conditions on positive affect, $F(2, 58) = 3.230$, $p < .05$, $\eta p^2 = .10$. Figure 3 shows a similar pattern in all three conditions: positive affect increased after running compared to before running. Increased scores between pre- and post-tests were greatest in the self-selected entertainment condition (Pre 24.3 ± 8.4; Post 28.9 ± 7.3), followed by the static image condition (Pre 25.4 ± 9.1; Post 28.9 ± 7.6) and were lowest in the dynamic image condition (Pre 26.8 ± 8.1; Post 28.2 ± 7.3). Differences in positive scores between the dynamic image and self-selected entertainment conditions narrowed at post-test compared to pre-test. Differences between the dynamic and static image conditions at pre-test were bigger than at post-test.

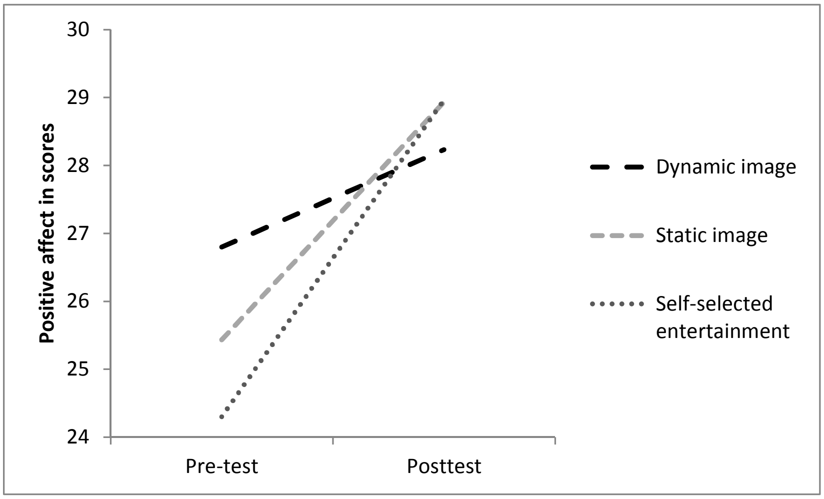

Figure 2. The interaction between the three conditions pre and post test

There was no main effect on negative affect of conditions, $F(1, 29) = .976$, $p > .05$, $\eta p^2 = .001$ and time, $F(2, 58) = .017$, $p > .05$, $\eta p^2 = .033$ (Dynamic-CI, 11.073 - 12.994; Image-CI, 11.119 - 12.315; Self-CI, 10.744 - 12.098; Pre-CI, 10.937 - 12.463; Post-CI, 11.224 - 12.265). There were no interactions between time and conditions on negative affect scores, $F(2, 58) = 2.504$, $p > .05$, $\eta p^2 = .079$. The negative scores changed across, the dynamic image (Pre 12.5 ± 4.4; Post 11.6 ± 1.6), the static image (Pre 11.5 ± 2.0; Post 12.0 ± 1.8), and the self-selected entertainment (Pre 11.2 ± 2.2; Post 11.7 ± 1.7), conditions.

4. Discussion

This study examined energy expenditure and psychological responses on indoor treadmill running, involving affordances emerging from presentation of dynamic and static images of nature compared to using self-selected entertainment (using earphones to listen to music or to watch TV on a screen). Results revealed no differences in energy expenditure across the three conditions, indicating no variations in amounts of energy expended during exercise by all participants supporting the first hypothesis. In contrast with data from previous studies [12, 20], this finding did not reveal differences in physical benefits from two different types of green physical activity and self-selected entertainment. In previous work, physical responses such as blood pressure, autonomic control of the heart and metabolic parameters have displayed positive effects of green physical activity. In this study, we presented three types of affordances for participants to perceive and utilise while they performed the same physical task in the same environmental setting. The affordances were limited for physical utilisation in this study because participants were not allowed to change the type of physical activity which might be why similar levels of energy expenditure output were observed. The data also indicated that, even though participants might not be familiar with running while looking at static or dynamic scenes of nature, the same level of energy expenditure was recorded as when people exercised using their own preferred entertainment, i.e. the things that they enjoyed and were familiar with.

The second hypothesis, i.e. that people would report more positive affect when running with nature-based affordances, compared to self-selected entertainment, was partly supported by the results. There were no changes in negative affect found in any conditions regardless of time, indicating that participants neither felt worse, nor experienced reduced negative feelings in any of the exercise conditions. This finding echoed findings of a similar study by Mayer and colleagues [21] which compared three groups, walking in a nature environment and walking indoors while viewing a dynamic nature or urban image, and which found no differences on negative affect. Our study partly endorsed the positive effects of green physical activity since positive affect was experienced when people viewed a static nature-based image, compared to viewing a dynamic image of a nature video when running on a treadmill for 20 minutes. This finding was in line with data from previous research [12, 21, 22], which supported effects of green physical activity on positive feelings. However, the affordances presented in these two studies [12, 22] were different to the affordances available in the current study. Pretty and colleges used thirty static images (four categories, 120 images in total) in a rotating slideshow during cycling which offered a different level of affordances for performers to utilise [12]. The main discrepancy in terms of affordances designed in the current study and in existing literature was based on a static image, multiple static images and a dynamic image with indoor exercise offering different affordances. A static image was a frozen moment of the optic flow whereas a dynamic image offered a continuously changing optic flow experience. Multiple static images accumulated various discrete images from different optic flows. In the study by Horiuchi et al., people were asked to sit in a forest with a limited viewing scene or sit in an enclosed environment [22]. In this setting, people could perceive rich and continuously affordances from visual, auditory and olfactory systems compared to exclusion of visual information. These studies all explored indoor green physical activity with various levels of nature-based affordances and all found evidence that positive effects would be accrued when participants performed physical activity in a higher level of nature, such as in nature vs built or urban scenes. However, our findings were somewhat controversial because people did not report experiencing more positive affect when viewing a dynamic image. Although a dynamic image should logically present richer affordances for performers to perceive and utilise, people who run on a treadmill might have found it hard because of some dissonance between their self-selected running speed and the running speed filmed on the dynamic image (5.2mph) or the provided information was too rich to be a hamper. This methodological explanation for the results needs to be tested in future research which could include a qualitative approach for an in-depth investigation. It is worth noting that similar findings have been reported in a study of people viewing static and dynamic displays [16]. Self-selected entertainment also played a positive role in improving participants' psychological feelings because people accrued greater positive affect in the self-selected entertainment condition than when viewing a dynamic image. The findings advance our knowledge of physical activity design by showing that changes in positive affect may not simply result from differences in dynamic or static imagery. Our results can be explained theoretically by the utilisation of different affordances rather than merely describing how people seem to react differently to various types of information sources during exercise. The theoretical rationale for our findings are supported by previous data reported by Wooller and colleagues who found that occlusion of different sensory information sources during green physical activity led to varied outcomes in mood, heart rate and perceived exertion [23]. In their study, participants were assigned to exercise in three conditions, visual occlusion (a nature video), sound occlusion (bird songs) and smell occlusion (pine oil), compared to a condition with full sensory availability. Results showed that the least influential factor on psychological states was visual information but that acoustic information had a clear effect on mood, heart rate and perceived exertion.

In the current study, there were some limitations which need to be taken into account. Participants' level of treadmill running experience was not considered and this could obscure the influence of different condition effects because experienced treadmill runners might have had their own treadmill preferences. Additionally, static and dynamic images of a single nature environment was selected and presented in this study; further study could explore presentation of images from different types of nature spaces, such as beaches, oceans, and forest trails as exercise environments.

5. Conclusion

The study aimed to examine the effects of different nature-based affordances for indoor treadmill running on physical and psychological measurement compared to popular gym condition. Furthermore, the scope of the study was limited to exercise in an indoor environment, in order to be relevant to individuals who typically engaged in popular gym based physical activity. Therefore the results cannot be generalised to physical activity behaviours in outdoor environments. Further study is needed to examine the effect of nature based affordances in outdoor environments. In summary, this study highlights some practical points for designing physical activity environments. First, people expended the same level of energy, whether they viewed a static or dynamic image or exercised with their own entertainment (dominated by visual/acoustic or visual affordances). Second, for participants who are physically active running on a treadmill while looking at a static image of a park scene of nature seems just as functional in enhancing positive affect, as choosing their preferred entertainment. Third, when given a choice, participants running on a treadmill choosing acoustic or acoustic/optic based affordances experience significantly enhanced psychological benefits. Further research needs to investigate effects of other important factors when designing exercise environments outdoors and indoors for different population groups like young children, elderly people and those with injuries or disease, since affordances may differ when different individuals directly interact with different information modalities and with nature.

References

[1] WHO. Physical activity Fact sheet N°385. 2015.
[2] WHO. Global recommendations on physical activity for health. Geneva World Heal Organ 2010:60. doi:10.1080/11026480410034349.
[3] WHO. Mental and neurological disorders. World Heal Organ Fact Sheet 2001:1–4. doi:10.1016/b978-0-7506-0898-5.50011-0.
[4] Nations U. World Urbanization Prospects: The 2014 Revision, Highlights (ST/ESA/SER.A/352). 2014. doi:10.4054/DemRes.2005.12.9.
[5] Gladwell VF, Brown DK, Wood C, Sandercock GR, Barton JL. The great outdoors: how a green exercise environment can benefit all. Extrem Physiol Med 2013;2:3. doi:10.1186/2046-7648-2-3.
[6] Akers A, Barton J, Cossey R, Gainsford P, Griffin M, Micklewright D. Visual Color Perception in Green Exercise: Positive Effects on Mood and Perceived Exertion. Environ Sicence Technol 2012;46:8861–6. doi:10.1021/es301685g.
[7] Brown DK, Barton JL, Gladwell VF. Viewing nature scenes positively affects recovery of autonomic function following acute-mental stress. Environ Sci Technol 2013;47:5562–9. doi:10.1021/es305019p.
[8] Moore EO. A prison environment's effect on health care service demands. J Environ Syst 1981;11:17–34. doi:10.2190/KM50-WH2K-K2D1-DM69.
[9] Shin WS. The influence of forest view through a window on job satisfaction and job stress. Scand J For Res 2007;22:248–53. doi:10.1080/02827580701262733.
[10] Ulrich RS. View through a window may influence recovery from surgery. Science 1984;224:420–1. doi:10.1126/science.6143402.
[11] Duncan MJ, Clarke ND, Birch SL, Tallis J, Hankey J, Bryant E, et al. The effect of green exercise on blood pressure, heart rate and mood state in primary school children. Int J Environ Res Public Health 2014;11:3678–88. doi:10.3390/ijerph110403678.
[12] Pretty J, Peacock J, Sellens M, Griffin M. The mental and physical health outcomes of green exercise. Int J Environ Health Res 2005;15:319–37. doi:10.1080/09603120500155963.
[13] Yeh H-P, Stone JA, Churchill SM, Wheat JS, Brymer E, Davids K. Physical, Psychological and Emotional Benefits of Green Physical Activity: An Ecological Dynamics Perspective. Sports Med 2015. doi:10.1007/s40279-015-0374-z.
[14] Gibson JJ. The ecological approach to visual perception. New Jersey: Lawrence Erlbaum Associates, Inc.; 1986.
[15] Brymer E, Davids K. Ecological dynamics as a theoretical framework for development of sustainable behaviours towards the environment. Environ Educ Res 2013;19:45–63. doi:10.1080/13504622.2012.677416.
[16] Heft, H.;Nasar JL. Evaluating Environmental Scenes Using Dynamic. Environement Behav 2000;32:301–22.
[17] Kilpatrick MW, Kraemer RR, Quigley EJ, Mears JL, Powers JM, Dedea AJ, et al. Heart rate and metabolic responses to moderate-intensity aerobic exercise: a comparison of graded walking and ungraded jogging at a constant perceived exertion. J Sports Sci 2009;27:509–16. doi:10.1080/02640410802668650.
[18] Watson D, Clark LA, Tellegen A. Development and Validation of Brief Measures of Positive and Negative Affect - the Panas Scales. J Pers Soc Psychol 1988;54:1063–70. doi:10.1037/0022-3514.54.6.1063.
[19] Brage S, Brage N, Franks PW, Ekelund U, Wareham NJ. Reliability and validity of the combined heart rate and movement sensor Actiheart. Eur J Clin Nutr 2005;59:561–70. doi:10.1038/sj.ejcn.1602118.
[20] Gladwell VF, Brown DK, Barton JL, Tarvainen MP, Kuoppa P, Pretty J, et al. The effects of views of nature on autonomic control. Eur J Appl Physiol 2012;112:3379–86. doi:10.1007/s00421-012-2318-8.
[21] Mayer FS, Frantz CM, Bruehlman-Senecal E, Dolliver K. Why Is Nature Beneficial?: The Role of Connectedness to Nature. Environ Behav 2009;41:607–43. doi:10.1177/0013916508319745.
[22] Horiuchi M, Endo J, Takayama N, Murase K, Nishiyama N, Saito H, et al. Impact of viewing vs. Not viewing a real forest on physiological and psychological responses in the same setting. Int J Environ Res Public Health 2014;11:10883–901. doi:10.3390/ijerph111010883.
[23] Wooller, J.J.;Barton, J.;Gladwell, V. F.;Micklewright D. Occlusion of sight, sound and smell during Green Exercise influences mood, perceived exertion and heart rate. Int J Envoironmental Heal Res 2015.